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Original Research Paper

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ANALYSIS OF TUMOR MARGIN SHRINKAGE IN THE RESECTED SPECIMEN OF SQUAMOUS CELL CARCINOMA OF THE ORAL CAVITY

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ABSTRACT **Background:** Oral squamous cell carcinoma (OSCC) is one of the most common malignancies in the head and neck region, particularly in developing countries. Achieving clear surgical margins is critical for minimizing recurrence and reducing the need for adjuvant therapy. However, discrepancies between intraoperative and final histopathological margins are frequently observed due to margin shrinkage. This study aimed to assess the extent and pattern of surgical margin shrinkage in OSCC across different stages of tissue handling. **Methods:** A prospective cross-sectional study was conducted on 100 patients with biopsyproven OSCC undergoing surgical resection. Tumor margins were measured at three stages: pre-incision (in-vivo), post-resection (in-vitro), and post-formalin fixation. Shrinkage was calculated between each stage, and associations with clinicopathological variables, such as tumor site and neoadjuvant therapy, were analyzed using appropriate statistical methods. **Results:** The mean surgical margin reduced from 10 mm pre-incision to 8.03 mm postresection and 7.4 mm post-fixation, with an average total shrinkage of 2.6 mm (26%). The greatest shrinkage occurred intraoperatively (1.96 mm), with minimal change post-fixation (0.63 mm). Margin shrinkage was more pronounced in tongue lesions (71.4%) and in patients receiving neoadjuvant therapy (61.1%). **Conclusion:** There is surgical margin shrinkage occurs in OSCC, primarily during the intraoperative phase. Surgeons should consider this contraction, especially in post-neoadjuvant cases and tongue cancers, to ensure adequate resection and avoid unnecessary adjuvant treatment. Accounting for shrinkage can enhance surgical precision and improve oncological outcomes.

KEYWORDS : Oral squamous cell carcinoma, surgical margins, margin shrinkage, tumor resection, histopathology, neoadjuvant therapy.

INTRODUCTION

Oral cavity malignancies are among the most prevalent forms of head and neck cancers, with squamous cell carcinoma (SCC) accounting for over 90% of all tumors arising from subsites such as the lips, tongue, buccal mucosa, gingiva, hard palate, floor of the mouth, and retromolar trigone [1-4]. These tumors may develop de novo or arise from pre-existing dysplastic lesions, often presenting late due to their insidious onset and subtle early symptoms [5,6].

Surgical resection remains the cornerstone of primary treatment for oral cavity squamous cell carcinoma (OSCC), irrespective of tumor stage. Achieving tumor-free margins is paramount, as margin status directly impacts local control and survival. A clear margin, defined histopathologically as a minimum of 5 mm from invasive tumor cells, significantly reduces the risk of local recurrence and the need for adjuvant therapy [7,8]. Conversely, close or positive margins are strongly associated with increased recurrence rates and are key determinants for recommending postoperative radiation or chemoradiation [7].

However, despite the surgeon's best efforts to obtain adequate margins intraoperatively, discrepancies often arise between in-vivo estimations and the final histopathological assessment. Several studies have demonstrated that surgical margins shrink significantly after resection and formalin fixation, with reported shrinkage ranging from 11% to as much as 59.02% [1,2, 9–13]. The variability in shrinkage and uncertainty regarding the phase at which maximum contraction occurs—whether intraoperative, post-resection, or post-fixation—poses a clinical challenge in margin interpretation and surgical planning.

This study aims to systematically analyze the extent and pattern of tumor margin shrinkage in OSCC, comparing in-vivo, post-excision, and post-fixation measurements. Understanding margin dynamics could inform surgical strategies and potentially prompt reconsideration of the currently recommended gross surgical margins to ensure optimal oncological clearance.

MATERIAL AND METHODS

Study Design And Participants

This study was a cross-sectional observational investigation conducted in the Department of Surgical Oncology after obtaining ethical clearance from the Institutional Ethics Committee.

The study enrolled 100 participants diagnosed with oral cavity squamous cell carcinoma (OSCC), all of whom were scheduled for surgical resection. Recruitment took place over a 10 month period, from September 2024 to June 2025. All patients were informed before their participation in the study and their written consent was obtained by them signing the informed consent sheet provided.

Inclusion criteria comprised patients aged 18 to 70 years of male and female, with biopsy confirmed OSCC without neoadjuvant treatment and received neoadjuvant chemotherapy or radiotherapy, who were deemed medically fit for general anesthesia based on preanesthetic evaluation,. Patients were excluded if they had a history of prior major oral surgeries, evidence of locoregional recurrence or distant metastases, or if they were diagnosed with connective tissue disorders. Informed written consent was obtained from all eligible participants prior to enrollment.

Preoperative Assessment And Surgical Protocol

Detailed demographic data, medical history, and physical examination findings were recorded using a structured proforma. All patients underwent the necessary radiological imaging, histopathological confirmation of OSCC, and preoperative workup. In the operating room, a 1 cm tumor margin was clinically identified through inspection and palpation. The tumor borders were outlined using a sterile surgical marker, and in-vivo margins (anterior, posterior, superior, and inferior) were precisely measured with a sterile ruler. The surgical margin was circumferentially marked, and a reference suture was placed to facilitate later correlation with histopathological findings.

Margin Measurement And Specimen Handling

Immediately after tumor resection, the in-vitro (post-resection) margin measurements were repeated using the same sterile ruler. The specimen was then fixed in 10% neutral buffered formalin. Additional measurements were taken 24 hours postoperatively, during the histopathology processing phase but before lamination. Final margin status was recorded from the histopathological report. This allowed for sequential comparison of margin lengths at three key stages: pre-incision (in-vivo), post-resection (in-vitro), and post-formalin fixation. The extent of margin shrinkage at each stage and the overall shrinkage were calculated, with attention given to identifying the phase showing the greatest reduction.

A. Pre-resection B. Post resection C. Post Formalin fixation
Figure 1. Images of the 3 Stages of measurement

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics for Macintosh, Versions 25.0 and 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations for continuous variables and percentages with 95% confidence intervals for categorical variables, were used to summarize the demographic and clinical data. Comparisons of margin shrinkage between stages were analyzed using post hoc one-way analysis of variance (ANOVA) and linear regression models. Associations between categorical variables were assessed using the Chi-square test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The present study included 100 patients with histologically confirmed oral squamous cell carcinoma. The cohort exhibited a marked male predominance (78%) and a mean age of 53.5 years, indicating that oral cancer continues to affect middle-aged men disproportionately— likely due to higher exposure to tobacco and areca nut. Buccal mucosa was the most common subsite involved (56%), followed by the anterior two-thirds of the tongue (28%). Most patients (84%) presented in advanced stages (T3–T4), highlighting delays in consultation and the aggressive nature of the disease in this population. Neoadjuvant treatment was administered in 18% of cases, reflecting the advanced tumor stages requiring downstaging before definitive surgery. [Table 1]

Table 1: Summary Of Demographic, Tumor, And Treatment Characteristics (n = 100)

Parameter	Category	Number of Patients (%)
Gender	Male	78 (78%)
	Female	22 (22%)
Age Range	18–70 years (mean 53.5 years)	-
Tumor Subsite	Buccal Mucosa	56 (56%)
	Tongue (anterior 2/3)	28 (28%)
	Lip	5 (5%)
	Hard Palate	4 (4%)
	Floor of Mouth	7 (7%)
T Stage	T1	9 (9%)
	T2	7 (7%)
	T3	46 (46%)
	T4	38 (38%)
Neoadjuvant Treatment	Not Received (NEOAD-)	82 (82%)
	Received (NEOAD+)	18 (18%)

Margin analysis revealed a progressive reduction across surgical stages, with mean margins reducing from 10 mm pre-incision to 8.03 mm post-resection, and further to 7.4 mm postformalin fixation. The most significant shrinkage occurred intraoperatively (mean 1.96 mm), while post-fixation shrinkage was relatively minor (0.63 mm). The overall margin reduction was 2.60 mm, which is clinically significant in determining surgical adequacy. [Table 2]

Table 2: Surgical Margins And Shrinkage Measurements

Phase / Parameter	Measurement
Mean Margin at Pre-incision	10.00 mm
Mean Margin at Post-resection	8.03 mm
Mean Margin at Post-formalin	7.40 mm
Overall Mean Margin	8.54 mm
Mean Shrinkage (Pre-incision to Post-resection)	1.96 mm
Mean Shrinkage (Post-resection to Post-formalin)	0.63 mm
Overall Mean Shrinkage	2.60 mm

More than half of the patients (56%) experienced around 2mm of margin shrinkage post-resection, while only 13% had shrinkage <1 mm. [Table 3] Tongue lesions showed the highest rate of significant shrinkage (>2mm) in 71.4% of patients, likely due to muscular elasticity and tissue mobility. Margin shrinkage was more common in patients who had received neoadjuvant therapy (61.1%), possibly due to treatment-induced fibrosis or tissue softening. [Table 4]

These findings underscore the need to factor in expected margin shrinkage—particularly in tongue lesions and post-neoadjuvant cases—during surgical planning to ensure oncologic safety. They also support the adoption of intraoperative strategies such as wider resections and margin assessment techniques to avoid inadequate resections and recurrence.

Table 3: Distribution Of Shrinkage And Subsite-wise Involvement

Shrinkage After Resection	No. of Patients	Formalin Shrinkage	No. of Patients
< 1 mm	13	No Shrinkage	60
> 1–2 mm	27	< 1–2 mm	39
> 2–3 mm	56	> 2 mm	1
> 3–4 mm	4		
> 4 mm	0		

Table 4: Subsite-wise Margin Shrinkage Between 2–3 Mm

Subsite	% of Patients with Shrinkage between 2–3 mm
Tongue (anterior 2/3)	71.4%
Buccal Mucosa	57%
Floor of Mouth	28.5%
Hard Palate	25%
Lip	20%

DISCUSSION

Achieving negative surgical margins is a cornerstone of curative-intent surgery in oral cavity squamous cell carcinoma (SCC), as it significantly reduces the risk of local recurrence and the need for adjuvant therapy. However, numerous studies have highlighted a consistent discrepancy between intraoperative surgical margins and histopathological margins, primarily due to tissue shrinkage occurring at various stages of tumor resection and processing. This study aimed to quantify surgical margin shrinkage in oral SCC resections and identify the phase at which maximum shrinkage occurs.

In our cohort of 100 patients with confirmed oral SCC, the majority were men (78%), with a mean age of 53.5 years, and most presented at advanced tumor stages (T3 and T4), requiring neoadjuvant treatment in 82% of cases. Buccal mucosa and anterior tongue were the most commonly involved subsites, reflecting regional etiological factors like smokeless tobacco use.

Surgical margins were measured in three phases: pre-incision, post-resection, and postformalin fixation. A significant shrinkage of 2.60 mm overall (95% CI: 1.01–4.18, $p=0.011$) was observed. The most substantial reduction occurred between the pre-incision and postresection stages, with a mean shrinkage of 1.96 mm (19.7% reduction, $p=0.009$), whereas postresection to post-formalin contributed an 0.63 mm shrinkage (12.7%, $p=0.083$), which was not statistically significant. These findings support the notion that the intrinsic tissue properties and handling during surgical excision contribute more to margin reduction than extrinsic factors like formalin fixation [14–16].

The findings of our study align closely with existing literature, affirming that significant surgical margin shrinkage occurs in oral squamous cell carcinoma (OSCC), primarily during the intraoperative phase. Burns et al. (2021) reported a 26% overall shrinkage—mirroring our data—with 19.7% occurring between pre-incision and post-resection and an insignificant 12.7% reduction post-fixation. Similarly, Mistry et al. [7] found a 22.7% intraoperative shrinkage, while Cheng et al. [8] observed up to 59.02%, especially in tongue lesions. El-Fol et al. [9] and Mohiyuddin et al. [10] reported 47.6% and 25% discrepancies, respectively, further confirming the variability across sites.

Vaidya et al. (2025) observed a higher overall shrinkage of 33.41%, with significant reductions at each processing stage—15.31% post-resection, 7.31% after fixation, and 10.79% posthistopathology. Unlike our study, which found increased shrinkage in tongue lesions (71.4%) and in patients receiving neoadjuvant therapy (61.1%), Vaidya et al. [1] did not find such associations. Nonetheless, their conclusion that pathological margins approximate two-thirds of surgical margins reinforces the importance of accounting for shrinkage during surgical planning to avoid inadequate resections or unnecessary adjuvant treatment.

This again emphasizes the clinical significance of accurately estimating intraoperative margins, especially in high-risk subsites or previously treated tissues.

While our findings highlight the need for initially wider surgical margins, the morbidity associated with aggressive resections—especially in the oral cavity where function and aesthetics are closely tied—must be balanced against the risk and cost of second surgeries or adjuvant chemoradiotherapy. Currently, there is no consensus or multicentric evidence correlating surgical margins >1 cm with significantly improved prognosis in oral SCC, and thus this remains an area of ongoing debate.

Moreover, the instrument used for tumor resection may influence tissue contraction and margin shrinkage. In our study, monopolar cautery was predominantly used, which may contribute to thermal artifacts and subsequent margin contraction. This variable should be considered in future studies. No published data to date directly compare resection tools (e.g., scalpel, monopolar, harmonic) in terms of shrinkage impact, and this presents a novel area for investigation [18].

Overall, the findings of this study underline the importance of accounting for margin shrinkage intraoperatively and suggest that tailoring surgical margins based on tumor subsite, prior treatment, and expected shrinkage patterns could optimize outcomes

CONCLUSION

This study highlights that surgical margin shrinkage in oral squamous cell carcinoma (OSCC) is both significant and clinically consequential, with an average reduction of 26% from pre-incision to histopathological analysis—predominantly occurring intraoperatively. Recognizing this shrinkage is essential to prevent false-positive close margins and unnecessary adjuvant treatment.

Shrinkage occurring particularly in mobile anatomical sites like the tongue, Buccal mucosa and also in patients receiving neoadjuvant therapy. Further analysis for instrument-related margin shrinkage (thermal injury-induced contraction-monopolar cautery) may uncover additional modifiable variable.

While the current standard recommends 1 cm margins, pre-emptive planning for shrinkage may require by extending some additional margins at the time of resection.

In conclusion, to establish standardized resection margin protocols, and potentially refine guidelines on adjuvant therapy decisions based on histopathological margin adequacy. Though, it requires multicentric prospective studies to validate these observations.

We declare that no competing interests exist.

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